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Adaptive Channel Estimation for Super-Resolution Sparse MIMO-OFDM

D.RAJINI
Student M.Tech
Department of ECE
Vaagdevi college of Engineering,Warangal,India

U.VENU
Assistant Professor
Department of ECE
Vaagdevi college of Engineering,Warangal,India

Abstract: **A multiple-input multiple (MIMO) communication system combined with the orthogonal frequency division multiplexing (OFDM) modulation technique can achieve reliable high data rate transmission over broadband wireless channels. The most important research topic in the wireless communications is the adaptive channel estimation where the channel is rapidly time-varying. In this paper performance analysis of channel estimation through adaptive channel estimation algorithms for estimating channel using different modulation scheme are investigated. a parametric sparse multiple input multiple output (MIMO)-OFDM channel estimation scheme based on the finite rate of innovation (FRI) theory, whereby super-resolution estimates of path delays with arbitrary values can be achieved. Meanwhile, both the spatial and temporal correlations of wireless MIMO channels are exploited to improve the accuracy of the channel estimation. The estimation of channel at pilot frequencies is based on Least Mean Square and Recursive Least Square channel estimation algorithm. I have compared the performances of channel estimation algorithm by measuring bit error rate vs. SNR with BPSK, QPSK 16-PSK and 256- PSK modulation schemes.**

Keywords: **MIMO-OFDM; Least Mean Square; Recursive Least Square *Terms*—Super-Resolution; Sparse Channel Estimation.**

I. INTRODUCTION

The growing demand of multimedia services and the growth of Internet related contents lead to increasing interest to high speed communications. The requirement for wide bandwidth and flexibility imposes the use of efficient transmission methods that would fit to the characteristics of wideband channels especially in wireless environment where the channel is very challenging. In wireless environment the signal is propagating from the transmitter to the receiver along number of different paths, collectively referred as multipath [1-4]. While propagating the signal power drops of due to the following effects: path loss, macroscopic fading and microscopic fading.

To achieve a high system capacity for multimedia applications in wireless communications, various methods have been proposed in recent years. Among them, the multiple inputs multiple output (MIMO) system using multiple antennas at both the transmitter and the receiver has attracted a lot of research interest due to its potential to increase the system capacity without extra bandwidth .The system capacity could be linearly increased with the number of antennas when the system is operating over flat fading channels.

In this letter, a more practical sparse MIMO-OFDM channel estimation scheme based on spatial and temporal correlations of sparse wireless MIMO channels is proposed to deal with arbitrary path delays. The main contributions of this letter are summarized as follows. First, the proposed scheme can achieve super-resolution estimates of arbitrary path delays, which is more suitable for wireless channels in practice. Second, due to the small scale of the transmit and receive antenna arrays compared to the long signal transmission distance in typical MIMO antenna geometry, channel impulse responses (CIRs) of different transmit-receive antenna pairs share common path delays [5], which can be translated as a common sparse pattern of CIRs due to the spatial correlation of MIMO channels. Meanwhile, such common sparse pattern is nearly unchanged along several adjacent OFDM symbols due to the temporal correlation of wireless channels [6], [7]. Compared with previous work which just simply extends the sparse channel estimation scheme in single antenna systems to that in MIMO by exploiting the spatial correlation of MIMO channels [5] or only considers the temporal correlation for single antenna systems [6], [7], the proposed scheme exploits both spatial and temporal correlations to improve the channel estimation accuracy. Third, we reduce the pilot overhead by using the finite rate of innovation (FRI) theory [8], which can recover the analog sparse signal with very low sampling rate, as a result, the average pilot overhead per antenna only depends on the channel sparsity level instead of the channel length.

OFDM transforms the frequency-selective fading channels into parallel flat fading sub channels, as long as the cyclic prefix (CP) inserted at the beginning of each OFDM symbol is longer than or equal to the channel length. The channel length means the length of impulse response of the channel as discrete sequence. The signals on each subcarrier can be easily detected by a time-domain or frequency-domain .Otherwise the effect of frequency selective fading cannot be completely eliminated, and inter-carrier interference (ICI) and inter-symbol interference (ISI) will be introduced in the received signal. Channel estimation techniques that could flexibly detect the signals in both cases and therefore channel estimation is important in MIMO-OFDM systems.

II. PROPOSED METHODOLOGY

A. Sparse Mimo Channel Model

The MIMO channel is shown in Fig. 1, and its following characteristics will be considered in this letter.

1) Channel Sparsity: In typical outdoor communication scenarios, the CIR is intrinsically sparse due to several significant scatterers [3], [5]. For an $Nt \times Nr$ MIMO system, the CIR $h(i,j)(t)$ between the ith transmit antenna and the jth receive antenna can be modeled as [1],

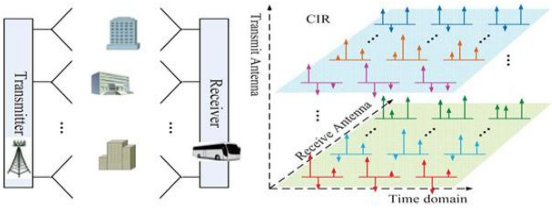

Fig. 1. Spatial and temporal correlations of wireless MIMO channels.

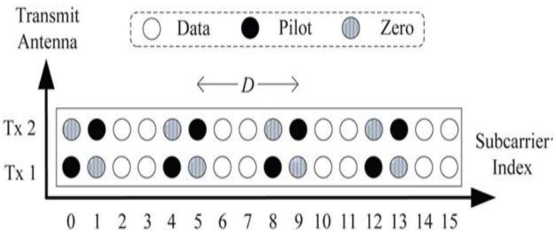

Fig. 2. Pilot pattern. Note that the specific Nt = 2, D = 4, Np = 4, and Np_total = 8 are used for illustration purpose.

2) Spatial Correlation: Because the scale of the transmit or receive antenna array is very small compared to the long signal transmission distance, channels of different transmit-receive antenna pairs share very similar scatterers.Meanwhile, for most communication systems, the path delay difference from the similar scatterer is far less than the system sampling period. Therefore, CIRs of different transmit-receive antenna pairs share a common sparse pattern, although the corresponding path gains may be quite different [5].

3) Temporal Correlation: For wireless channels, the path delays vary much slowly than the path gains, and the path gains vary continuously [6]. Thus, the channel sparse pattern is nearly unchanged during several adjacent OFDM symbols, and the path gains are also correlated [7].

B. MIMO-OFDM System

When generated OFDM signal is transmitted through a number of antennas in order to achieve diversity or higher transmission rate then it is known as MIMO-OFDM. Like any other communication system MIMO-OFDM system also has transmitter and receiver but the antennas are more than one both at transmit and receive end. MIMO system can be implemented in various ways, if we need to take the diversity advantage to combat fading then we need to send the same signals through various MIMO antennas and at the receiving end all the signals received by MIMO antennas will receive the same signals traveled through various path. If we are inserted to use MIMO for capacity increase then we can send different set of data via a number of antennas and the same number of antennas will receive the signals in the receiving end.

Channel estimation and equalization is an essential problem in OFDM system design. Basic task of equalizer is to compensate the influences of the channel .The major challenge faced in MIMO-OFDM systems is how to obtain the channel state information accurately and promptly. We consider MIMO–OFDM systems with two transmit antennas and two receive antenna as shown in fig.3.

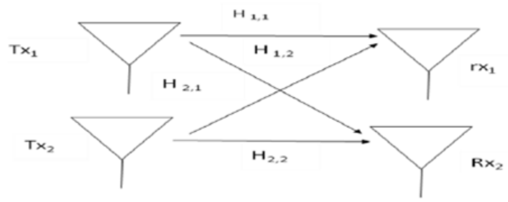

Fig 3.MIMO-OFDM System with 2 transmitting antenna and tworeceiving antenna

For coherent detection of information symbols, the blind channel estimation is carried out by evaluating the statistical information of the channel and certain properties of the transmitted signals. This compensation requires, however, than an estimate of the channel response is available. Often the channel frequency response or impulse response is derived from training sequence or pilot symbols, but it is also possible to use non pilot aided approaches like blind equalizer algorithms. Channel estimation is one of the fundamental issues of OFDM system design, without it non coherent detection has to be used, which incurs performance loss of almost 3-4Db compared to coherent detection. If coherent OFDM system is adopted, channel estimation becomes a requirement and usually pilot tones are used for channel estimation. Conventionally the receiver firstly obtain tentative channel estimates at the positions of the pilot symbols by means of modulation and then compute final channel estimates by means of interpolation.

C. Training Sequence Based Channel Estimation

Based on the assumptions such as perfect synchronization and block fading, a MIMO-OFDM system is design. In training based channel estimation algorithms, training symbols or pilot tones that are known to the receiver, are multiplexed along with the data stream for channel estimation. The idea behind these methods is to develop knowledge of transmitted pilot symbols at the receiver to estimate the channel. For a block fading channel, where the channel is constant over a few OFDM symbols, the pilots are transmitted on all subcarriers in periodic intervals of OFDM blocks. The channel estimates from the pilot subcarriers are interpolated to estimate the channel at the data subcarrier. This type of pilot arrangement, given in Fig.3 is called the block type arrangement. In block-type pilot based channel estimation, OFDM channel estimation symbols are transmitted periodically, in which all subcarriers are used as pilots. If the channel is constant during the block, there will be no channel estimation error since the pilots are sent at all carriers.

For a fast fading channel, where the channel changes between adjacent OFDM symbols, the pilots are transmitted at all times but with an even spacing on the subcarriers, representing a comb type pilot placement, This type of pilot arrangement, given in Fig.4 is called the comb type arrangement

D. Adaptive Channel Estimation

The most important research topic in the wireless communications is the adaptive channel estimation where the channel is rapidly time-varying. An adaptive algorithm is a process that changes its parameters as it gain more information of its possibly changing environment. The channel estimation methods like least square estimation and recursive least square which uses adaptive estimator which are able to update parameters of the estimator continuously, so that knowledge of channel and noise statistics are not required. The LMS and RLS CE algorithm requires knowledge of the received signal only. This can be done in a digital communication system by periodically transmitting a training sequence that is known to the receiver.

The adaptive channel estimation scheme is given in fig.4.

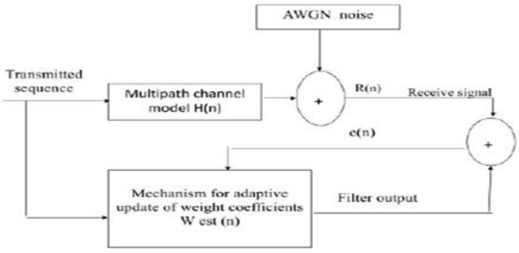

Fig 4. adaptive channel estimation scheme

i. Least Mean Square

The signal X(n) is transmitted via a time-varying channel H(n), and corrupted by an additive noise. The main aim of most channel estimation algorithms is to minimize the mean squared error i.e., between the received signal and its estimate In the Fig 4.1, we have unknown multipath fading channel, that has to be estimated with an adaptive filter whose weight are updated based on some criterion so that coefficients of adaptive filter should be as close as possible to the unknown channel. The output from the channel can be expressed as:

$$Y(n)=X(n)H(n)+W(n)$$

Output of adaptive filter is given as, P(n)=Westi(n)X(n) Where Westi =estimated channel coefficient at time n.

The priori estimated error signal needed to update the weights of the adaptive filter is, \

$$e(n)=Y(n)-P(n)= X(n) H(n)+W(n) - Westi(n)X(n)$$

Where e(n) minimized the mean square error. Now Cost function for adaptive filter structure given as

$$j (n)=E[e(m)e^*(m)]$$

$$j(n)=\zeta r\ 2-C(n) -C(n)Westi(n)-Westi(n)C(n)+D(m)WT\ esti\ (n)Westi(n)$$

Where ζr 2 is variance of received signal.

C(m)=[(X(n)Y(n)] is the cross correlation vector between input vector and received vector.

D(m)=E[X(n)XT(n)] is the correlation matrix between Gradient of cost function j(n) is given as

$$\Delta j(n)=-2C(n)+2D(m)\ Westi\ (n) = -2X(n)Y^*(n)+2X(n)X(n)\ Westi\ (n)$$

By using this **least mean square** equation is given as **Westi (n+1)= Westi (n)-1/2ηX(n)e*(n)**

Where, Westi (n+1) =weighted vector and η=LMS step size.

ii. Recursive Least Square

RLS algorithm required all the past sample of input and estimated output at each iteration. The objective function of a RLS CE algorithm is defined as an exponential weighted sum of errors square.

C(m)= Σ λ n-m eH(n)e(n)+δλmHH(n)H(n)

Where δ=positive real no. called regularization parameter (n) is the prior estimation error, and λ is the exponential forgetting factor with 0 < λ < 1. The prior estimation error is the difference between the desired response and estimation signal. Prior estimation error is given as,

e (n)= WH(n)x(n)

The objective function is minimized by taking the partial derivatives with respect to W(n) and setting the results equal to zero.

W (n)=R-1(n) Rsh(n)

Where R-1(n) =auto covariance matrix Rsh(n)= cross covariance matrix. Now from this **Recursive Least Square** equation is given as,

H(n)=H(n-1)+K(m)[W(n)-HH(n-1)X(n)]H

=H (n-1) +K (m)εH(n)

Where ε(n)= W(n)-HH(n-1)X(n) and K(m)= R-1(n)X(n)

III. SIMULATION RESULTS

A simulation study was carried out to compare the performance of the proposed scheme with those of the existing state-of-the-art methods for MIMO-OFDM systems. The conventional comb-type pilot and time-domain training based orthogonal pilot (TTOP) [2] schemes were selected as the typical examples of the nonparametric channel estimation scheme, while the recent time-frequency joint (TFJ) channel estimation scheme [4] was selected as an example of the conventional parametric scheme. OFDM system parameters used in the simulation, We assume to have perfect synchronization since the aim is to observe channel estimation performance. We have chosen the guard interval to be greater than the maximum delay spread in order to avoid inter-symbol interference.

In this paper we compare the least mean square and recursive least square channel estimation techniques on the basis of different modulation schemes. Comparison of LMS and RLS are shown in following fig by using above parameter. The complexity of RLS estimator is larger than LMS estimator but give better performance than LMS

IV. CONCLUSION

In this paper channel estimation based Least square, Minimum Mean Square Least mean square (LMS) and Recursive Least square of MIMO OFDM based systems are studied.. The complexity of RLS is larger than other estimators. The RLS estimator has good performance but high complexity. The LMS estimator has low complexity but its performance is not as good as that RLS at low SNRs. Simulation results show that estimation for MIMO OFDM provides less BER than other systems. Lastly by comparing the performance of RLS with LMS, it is observed that the RLS is more resistant to the noise in terms of the channel estimation.

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